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Abstract

A method and apparatus are described for sensing the absolute humidity of gases where the relative humidity of gases are measured, the humidity transducer is heated, the resulting temperature measured and the absolute humidity calculated (based on the power to heat said transducer, the temperature of said transducer and the relative humidity). In further embodiments the humidit transducer may be heated to a pasteurisation temperature, to substantially kill any common pathogens present on the humidity transducer. The flow rate may be determined to estimate a more instantaneous valve of humidity. The operation of the sensor may be continually monitored for correct operation and various constructions disclosed

for improving the efficiency of operation.

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CLAIMS

1. A humidity sensing apparatus for sensing the absolute humidity of gases comprising:

a humidity transducer providing a first signal, said first signal indicative of the relative humidity of said gases, Characterised in that said apparatus further comprising

heating means associated with or in substantial thermal contact with said humidity transducer and adapted to heat at least a portion of said humidity transducer depending on energisation power supplied thereto, temperature sensing means associated with or in substantial thermal contact with said humidity transducer and providing a second signal, said second signal indicative of the temperature of said humidity transducer, and control means adapted to provide a first said energisation power to said heating means to heat said humidity transducer to an operating temperature and receives said first signal and said second signal and calculates an estimate of the absolute humidity of said gases based thereon, wherein at least at some point during the operation of said apparatus said control means adapted to provide a second said energisation power to said heating means to heat said humidity transducer to a pasteurisation temperature, said pasteurisation temperature being adequate to substantially kill any common pathogens present on said humidity transducer.

2. A humidity sensing apparatus as claimed in claim 1 wherein said pasteurisation temperature is above 60 DEG C.

3. A humidity sensing apparatus as claimed in claims 1 or 2 wherein said operating temperature is above the temperature of

said gases.

4. A humidity sensing apparatus for sensing the absolute humidity of a flow of gases comprising:

a humidity transducer providing a first signal, said first signal indicative of the relative humidity of said flow of gases,
Characterised in that said apparatus further comprising

heating means associated with or in substantial thermal contact with said humidity transducer and adapted to heat at least a portion of said humidity transducer depending on energisation power supplied thereto,
temperature sensing means associated with or in substantial thermal contact with said humidity transducer and providing a second signal, said second signal indicative of the temperature of said humidity transducer and,
control means having storage means, and adapted to execute instructions stored in said storage means, said instructions comprising steps of:

- (i) providing a first said energisation power to said heating means to heat said humidity transducer to an operating temperature;
- (ii) receiving said first signal and said second signal;
- (iii) calculating an estimate of the absolute humidity of said flow of gases based on at least one of said first signal and/or said second signal;
- (iv) storing information on said absolute humidity over a period of time;
- (v) estimating the flow rate of said flow of gases based on at least one of said first signal, said second signal and/or said energisation power supplied to said heating means;
- (vi) storing information on said flow rate of said gases over said period of time in said storage means; and
- (vii) calculating a corrected absolute humidity value for said flow of gases during a portion of said period of time based on said information on said flow rate of gases during said portion in relation to said information on said flow rate of gases over said period of time and said information on said absolute humidity.

5. A humidity sensing apparatus as claimed in claim 4 wherein said period of time at least relates to one breathing cycle of a patient receiving respiratory therapy using said flow of gases.

6. A humidity sensing apparatus as claimed in claims 4 or 5 wherein said portion of said period of time relates to the inspiratory phase of said patient's breathing cycle.

7. A humidity sensing apparatus as claimed in any one of claims 4 to 6 wherein said humidity sensing apparatus further comprises a flow rate sensor, providing a third signal, said third signal being indicative of the flow rate of said flow of gases and said step (v) instead comprising determining the flow rate of said flow of gases based on said third signal.

8. A humidity sensing apparatus for sensing the absolute humidity of gases comprising:

a humidity transducer providing a first signal, said first signal indicative of the relative humidity of said gases,
Characterised in that said apparatus further comprising

heating means associated with or in substantial thermal contact with said humidity transducer and adapted to heat at least a portion of said humidity transducer depending on energisation power supplied thereto,
temperature sensing means associated with or in substantial thermal contact with said humidity transducer and providing a second signal, said second signal indicative of the temperature of said humidity transducer, and
control means adapted to provide a first said energisation power to said heating means to heat said humidity transducer to an operating temperature and receives said first signal and said second signal and calculate an estimate of the absolute humidity of said gases based thereon,
wherein at least at some point during the operation of said apparatus said control mean adapted to determine whether the apparatus is operating correctly, based on at least one of said first signal, said second signal and/or said energisation power provided to said heating means.

9. A humidity sensing apparatus as claimed in claim 8 wherein said correct operation of said apparatus at least relates to whether said estimate of the absolute humidity of said gases is accurate within predetermined limits.

10. A humidity sensing apparatus as claimed in claims 8 or 9 wherein said accuracy of said absolute humidity is monitored in at least one aspect by detecting the presence of liquid water on said humidity transducer,

11. A humidity sensing apparatus as claimed in any of claims 8 to 10 wherein said detection of liquid water comprises the steps:

- a) storing absolute humidity values during normal operation;
- b) providing a third said energisation power to said heating means to heat said humidity transducer to the dewpoint of said gases (where the relative humidity just reaches 100%);
- c) comparing the absolute humidity reading at dew point with that during normal operating (stored in step (a)): and if there is a substantial difference providing a fourth signal indicative of incorrect or faulty operation.

12. A humidity sensing apparatus as claimed in any one of claims 8 to 10 wherein said detection of liquid water comprises the steps of:

- a) determining whether said first signal indicates 100% relative humidity,
- b) providing a fourth said energisation power to said heating means to heat said humidity transducer to a substantially higher temperature;
- c) if the relative humidity does not reduce from 100% providing a fourth signal indicative of incorrect or faulty operation.

13. A humidity sensing apparatus as claimed in claims 11 or 12 wherein if said fourth signal indicates incorrect or faulty operation said control means provides a fifth said energisation power to said heating means to heat said humidity transducer to substantially evaporate said liquid water therefrom.

14. A humidity sensing apparatus as claimed in claims 11 or 12 wherein, if said fourth signal indicates incorrect or faulty operation said control means discontinuing said energisation power to said heating means, and using said second signal to estimate an upper limit for the absolute humidity of said flow of gases.

15. A gases delivery apparatus for supplying a flow of gases to a patient comprising:

cases supply means adapted to provide a flow of gases at a desired pressure,
 humidification means having an inlet and an outlet, said inlet adapted to be in fluid communication with said gases supply means said humidification means thereby providing water vapour to humidify said flow of gases as they pass through said humidification means,

Characterised in that said apparatus further comprising

a conduit adapted to be connected to said outlet and accepting said flow of gases therefrom, said conduit including an interior and an exterior, said conduit conveying said flow of gases through said interior, and including a protrusion located in said interior, and

humidity sensing means adapted to be located in said interior providing an estimate of the absolute humidity of said flow of gases, in use said humidity sensing means juxtaposed below said protrusion, said protrusion thereby substantially preventing any liquid water from flowing down said conduit onto said humidity sensing means.

16. A gases delivery apparatus as claimed in claim 15 wherein said gases conduit having an aperture including a keyway, said humidity sensing means comprising a humidity transducer provided in a sensor housing, said housing adapted to engage with said aperture and having a key which engages with said keyway in said aperture such that said housing can only be installed in said aperture in a single orientation.

17. A gases delivery apparatus as claimed in claim 15 wherein said humidity sensing means is permanently housed within said conduit.

18. A method of sensing the absolute humidity of gases comprising the steps:

using a humidity transducer to sense the relative humidity of said gases,
 Characterised in that said apparatus further comprising

heating at least a portion of said humidity transducer and sensing the temperature of said humidity transducer, and calculating an estimate of the absolute humidity of said gases based on the power to heat said transducer, the temperature of said transducer and/or the relative humidity and
 heating said humidity transducer to a pasteurisation temperature, said pasteurisation temperature being adequate to

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substantially kill any common pathogens present on said humidity transducer.

19. A method of sensing the absolute humidity of gases comprising the steps:

using a humidity sensor to sense the relative humidity of said gases,
Characterised in that said apparatus further comprising

heating at least a portion of said humidity sensor to an operating temperature,
calculating an estimate of the absolute humidity of said flow of gases based on at least one of said relative humidity and/or temperature of said sensor,
storing information on said absolute humidity over a period of time,
estimating the flow rate of said flow of gases based on at least one of said relative humidity, said temperature and/or the power required to heat said transducer,
storing information on said flow rate of said gases over said period of time, and
calculating a corrected absolute humidity value for said flow of gases during a portion of said period of time based on said information on said flow rate of gases during said portion in relation to said information on said flow rate of gases over said period of time and said information on said absolute humidity.

20. A method of sensing the absolute humidity of gases comprising the steps:

using a humidity sensor to sense the relative humidity of said gases,
Characterised in that said apparatus further comprising

heating at least a portion of said humidity sensor to an operating temperature,
calculating an estimate of the absolute humidity of said gases based on at least one of said relative humidity, said temperature and the power required to heat said sensor detecting whether the apparatus is operating correctly, based on at least one of said relative humidity, said temperature and/or the power required to heat said sensor.

21. A method of sensing the absolute humidity of gases comprising the steps:

providing a flow of gases at a desired pressure,
humidifying said flow of gases,
Characterised in that said apparatus further comprising

conveying said flow of gases through the said interior of a conduit and providing a protrusion in said interior,
positioning a humidity sensor below said protrusion, said protrusion thereby substantially preventing any liquid water from flowing down said interior onto said humidity sensor, and
providing an estimate of the absolute humidity of said flow of gases, based at least from the output of said humidity sensor.

DESCRIPTION

FIELD OF THE INVENTION

[0001] The present invention relates to the use of heated humidity sensors particularly though not solely to the use of heated humidity sensors with respiratory humidifiers for assisted patient breathing.

BACKGROUND OF THE INVENTION

[0002] Heated humidity sensors are hereby described that allow the measurement of humidity in gases having a dewpoint above the temperature of the surrounding environment. Problems associated with such gas streams include lack of sensor accuracy at high relative humidity and the possibility of liquid condensate flowing onto the sensor. A further disadvantage of

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measurement in high dewpoint gases is the possibility of sensor failure or misreading.

[0003] Such humidity sensors could be used, for example, as part of a humidity-controlled medical humidifier. This introduces design constraints such as small size, robustness and ability to be sterilised to prevent cross-contamination between patients.

[0004] When a medical humidifier is used with a respiratory ventilator, gas flow and absolute humidity can change rapidly in a cyclic manner. These changes typically happen faster than the response time of the humidity sensor, which gives a "time average" of the humidity surrounding it. This means that certain key humidity parameters, such as average absolute humidity during the inspiratory part of the flow cycle, are unable to be measured.

[0005] In United States Patent number 4,143,177 capacitive-type humidity sensor is described, as well as how a heater and temperature sensor can be incorporated into the humidity sensor to allow stable temperature control of the humidity sensor at temperatures above that of the surrounding gas. This enables the humidity sensor to avoid condensation in gases of high humidity. The heater can be manufactured around or underneath the humidity sensor. It also describes how the heater element can be simultaneously used to measure temperature, i.e. the heater element and temperature sensor are combined in one element. This makes sensor construction easier.

[0006] United States Patent No. 5,777,206 also describes a heated capacitive-type humidity sensor. A single resistor is used in this patent both as a heater and a temperature sensor, for controlling the humidity sensor temperature above the gas temperature. US5,777,206 also describes calculating the absolute or relative humidity from knowledge of the temperature of the sensor. Further disclosure includes a method for determining the gas flow rate based on the amount of heat being supplied to the heated capacitive sensor to determine the gas flow rate past the sensor. Whereas US5,777,206 uses a resistor to provide sensor heating and temperature measurement, US4,143,177 uses a P-N semiconductor diode junction to provide the same functions.

SUMMARY OF THE INVENTION

[0007] It is therefore an object of the present invention to provide a heated humidity sensor which goes some way to overcoming the abovementioned disadvantages in the prior art or which will at least provide the industry with a useful choice.

[0008] Accordingly in a first aspect the present invention consists in a humidity sensing apparatus for sensing the absolute humidity of gases comprising:

a humidity transducer providing a first signal, said first signal indicative of the relative humidity of said gases, heating means associated with or in substantial thermal contact with said humidity transducer and adapted to heat at least a portion of said humidity transducer depending on energisation power supplied thereto, temperature sensing means associated with or in substantial thermal contact with said humidity transducer and providing a second signal, said second signal indicative of the temperature of said humidity transducer, and control means adapted to provide a first said energisation power to said heating means to heat said humidity transducer to an operating temperature and receives said first signal and said second signal and calculates an estimate of the absolute humidity of said gases based thereon, wherein at least at some point during the operation of said apparatus said control means adapted to provide a second said energisation power to said heating means to heat said humidity transducer to a pasteurisation temperature, said pasteurisation temperature being adequate to substantially kill any common pathogens present on said humidity transducer.

[0009] In a second aspect the present invention consists in a humidity sensing apparatus for sensing the absolute humidity of a flow of gases comprising:

a humidity transducer providing a first signal, said first signal indicative of the relative humidity of said flow of gases, heating means associated with or in substantial thermal contact with said humidity transducer and adapted to heat at least a portion of said humidity transducer depending on energisation power supplied thereto, temperature sensing means associated with or in substantial thermal contact with said humidity transducer and providing a second signal, said second signal indicative of the temperature of said humidity transducer and, control means having storage means, and adapted to execute instructions stored in said storage means, said instructions comprising steps of:

(i) providing a first said energisation power to said heating means to heat said humidity transducer to an operating

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temperature;

(ii) receiving said first signal and said second signal;

(iii) calculating an estimate of the absolute humidity of said flow of gases based on at least one of said first signal and/or said second signal;

(iv) storing information on said absolute humidity over a period of time;

(v) estimating the flow rate of said flow of gases based on at least one of said first signal, said second signal and/or said energisation power supplied to said heating means;

(vi) storing information on said flow rate of said gases over said period of time in said storage means; and

(vii) calculating a corrected absolute humidity value for said flow of gases during a portion of said period of time based on said information on said flow rate of gases during said portion in relation to said information on said flow rate of gases over said period of time and said information on said absolute humidity.

[0010] In a third aspect the invention may broadly be said to consist in a humidity sensing apparatus for sensing the absolute humidity of gases comprising:

a humidity transducer providing a first signal, said first signal indicative of the relative humidity of said gases, heating means associated with or in substantial thermal contact with said humidity transducer and adapted to heat at least a portion of said humidity transducer depending on energisation power supplied thereto,

temperature sensing means associated with or in substantial thermal contact with said humidity transducer and providing a second signal, said second signal indicative of the temperature of said humidity transducer, and

control means adapted to provide a first said energisation power to said heating means to heat said humidity transducer to an operating temperature and receives said first signal and said second signal and calculate an estimate of the absolute humidity of said gases based thereon,

wherein at least at some point during the operation of said apparatus said control mean adapted to determine whether the apparatus is operating correctly, based on at least one of said first signal, said second signal and/or said energisation power provided to said heating means.

[0011] In a fourth aspect the present invention to consists in a gases delivery apparatus for supplying a flow of gases to a patient comprising:

gases supply means adapted to provide a flow of gases at a desired pressure,

humidification means having and inlet and an outlet, said inlet adapted to be in fluid communication with said gases supply means said humidification means thereby providing water vapour to humidify said flow of gases as they pass through said humidification means,

a conduit adapted to be connected to said outlet and accepting said flow of gases therefrom, said conduit including an interior and an exterior, said conduit conveying said flow of gases through said interior, and including a protrusion located in said interior, and

humidity sensing means adapted to be located in said interior providing an estimate of the absolute humidity of said flow of gases, in use said humidity sensing means juxtaposed below said protrusion, said protrusion thereby substantially preventing any liquid water from flowing down said conduit onto said humidity sensing means.

[0012] In a fifth aspect the present invention to consists in a method of sensing the absolute humidity of gases comprising the steps:

using a humidity transducer to sense the relative humidity of said gases,

heating at least a portion of said humidity transducer and sensing the temperature of said humidity transducer, and

calculating an estimate of the absolute humidity of said gases based on the power to heat said transducer, the temperature of said transducer and/or the relative humidity and

heating said humidity transducer to a pasteurisation temperature, said pasteurisation temperature being adequate to substantially kill any common pathogens present on said humidity transducer.

[0013] In a sixth aspect the present invention to consists in a method of sensing the absolute humidity of gases comprising the steps:

using a humidity sensor to sense the relative humidity of said gases,

heating at least a portion of said humidity sensor to an operating temperature,

calculating an estimate of the absolute humidity of said flow of gases based on at least one of said relative humidity and/or

temperature of said sensor,
 storing information on said absolute humidity over a period of time,
 estimating the flow rate of said flow of gases based on at least one of said relative humidity, said temperature and/or the power required to heat said transducer,
 storing information on said flow rate of said gases over said period of time, and
 calculating a corrected absolute humidity value for said flow of gases during a portion of said period of time based on said information on said flow rate of gases during said portion in relation to said information on said flow rate of gases over said period of time and said information on said absolute humidity.

[0014] In a seventh aspect the present invention consists in a method of sensing the absolute humidity of gases comprising the steps:

using a humidity sensor to sense the relative humidity of said gases,
 heating at least a portion of said humidity sensor to an operating temperature
 calculating an estimate of the absolute humidity of said gases based on at least one of said relative humidity, said temperature and the power required to heat said sensor detecting whether the apparatus is operating correctly, based on at least one of said relative humidity, said temperature and/or the power required to heat said sensor.

[0015] In an eighth aspect the present invention consists in a method of sensing the absolute humidity of gases comprising the steps:

providing a flow of gases at a desired pressure,
 humidifying said flow of gases,
 conveying said flow of gases through the said interior of a conduit and providing a protrusion in said interior,
 positioning a humidity sensor below said protrusion, said protrusion thereby substantially preventing any liquid water from flowing down said interior onto said humidity sensor, and
 providing an estimate of the absolute humidity of said flow of gases, based at least from the output of said humidity sensor.

[0016] To those skilled in the art to which the invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the scope of the invention as defined in the appended claims. The disclosures and the descriptions herein are purely illustrative and are not intended to be in any sense limiting.

[0017] The invention consists in the foregoing and also envisages constructions of which the following gives examples.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] One preferred form of the present invention will now be described with reference to the accompanying drawings in which;

Figure 1 is a cutaway view of the conduit according to the preferred embodiment of the present invention in use,
 Figure 2 is a close up side view of the humidity sensor according to the preferred embodiment of the present invention,
 Figure 3 is a diagram of a system for delivering humidified gases to a patient according to the preferred embodiment of the present invention, and
 Figure 4 is a block diagram of the control system according to the preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] The present invention relates to a humidity sensor which is designed:

1. To operate in high dewpoint situations where the relative humidity may be high, and liquid water may be present.
2. To detect sensor misreading or failure.
3. To be strong, robust and capable of sterilisation.

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4. When flow is rapidly changing in a cyclic manner, to detect key parameters of the instantaneous absolute humidity waveform by mathematically combining the reading from the humidity sensor with knowledge of the gas flow waveform.

[0020] Polymer absorption sensors are well known in the prior art and consist of two parts: a water-vapour porous polymer matrix, and a set of electrical sensing electrodes. The amount of water vapour which is absorbed into the polymer matrix is determined by the relative humidity of the gas in close contact with the polymer matrix. The electrodes allow the measurement of electrical properties related to the amount of water vapour in the polymer matrix. Usually capacitance of the electrodes is measured, as the permittivity of the matrix changes with water content. Alternatively electrical resistance or impedance can be measured.

[0021] The invention as shown consists of a relative humidity sensor 1, which is mounted in close thermal contact with a heater 2 and a separate temperature sensor 3 to form assembly 11. Measurement circuitry 4 is connected to the humidity sensor 1 and gives an output in relative humidity 5. An adjustable power supply 6 is connected to the heater 2. Measurement circuitry 7 is connected to temperature sensor 3 to give a temperature signal 8 at its output. Control system 9 takes the temperature signal 8 and generates a control signal 10 so that temperature signal 8 remains constant at the desired temperature. In this way all of the elements of assembly 11 are kept at a constant temperature. The relative humidity sensor 1 is preferably of the polymer absorption type. Preferably the sensing mechanism measures capacitance of the polymer matrix 13 using the electrodes 12, although it could alternatively use resistance or impedance measurements of the polymer matrix.

[0022] Absolute humidity of a gas can be calculated if the relative humidity and temperature are both known. This calculation is based on well-known physical principles. Due to its mode of operation, the polymer sensor measures the relative humidity of the measured gas at the temperature of the polymer matrix 13. Therefore absolute humidity of the gas can be calculated from the relative humidity measured by sensor 1 and the temperature of sensor 1 as measured by temperature sensor 3.

[0023] If the polymer matrix is heated by applying heat to heater 2 the measured relative humidity will decrease, however the calculated absolute humidity will remain constant because the absolute humidity of the gas has not changed. Although we still get the same absolute humidity reading from the sensor, there are several advantages that come from heating the sensor. Firstly, formation of condensate on the sensor can be prevented. Secondly, we can measure humidity of gas with a dewpoint above the temperature of the surrounding environment. Lastly, by keeping the sensor at a high temperature we are running it in the low relative humidity region where most sensors are more accurate and linear.

[0024] Such a sensor can be used for measuring absolute humidity of any gases. However preferably the sensor is to be used for measuring medical gases. Preferably the medical gases are also respiratory gases, such as are found in a patient breathing circuit. A breathing circuit can be used to connect a patient to either a source of flowing gases, or to a respiratory ventilator.

[0025] Preferably the sensor is heated above the temperature of the gas to be measured, although it may be heated to any desired temperature. Preferably the temperature sensor 3 and heater 2 are separate components that are both thermally linked by being part of assembly 11. US4,143,177 and US5,777,206 both describe systems where the temperature sensing and heating functions are combined in a single component.

[0026] Since there will be times when the sensing assembly 11 will be in an environment containing liquid water while the heater is off, it is essential that humidity sensor 1 be a water resistant sensor. Such sensors have only recently become available. Such a sensor will recover quickly from contact with liquid water, and this will have no lasting effects on the humidity calibration.

[0027] The sensor as described may be mounted in several different ways. In one embodiment a probe 110 could be inserted into a hole 18 in a tube 109 to measure the humidity of the gas inside 14, as shown in Figure 1. An alternative arrangement would be as a sensor permanently mounted inside a tube. With either arrangement it may be desirable to orient the sensing element in a particular direction in the tube. For instance, a horizontally facing sensing element 1 will cause liquid water on the sensor assembly 11 to run off the probe rather than onto the sensing element. To allow positive location of a probe type sensor in a tube, a key 15 and keyway 16 can be used, as shown in Figure 1.

[0028] There are other ways of preventing liquid water from running onto the humidity probe and affecting the humidity reading. For example consider the apparatus shown in Figure 3. A respiratory system for delivering humidified gases to a patient 100 is shown, including a gases supply 102, a humidifier 104, a conduit 106 connecting the gases supply 102 to the humidifier 104, and a conduit 108 connecting the humidifier 104 to the patient 100. In the configuration shown in Figure 3 it is seen that the conduit 108 conveying air flow from the humidifier 104 is substantially vertical in the section 109 immediately adjacent the humidifier 104. In the preferred embodiment of the present invention the humidity sensor 110 would be located in this vertical section 109. In this fashion any liquids that were to condense in this vertical section 109

would likely flow down the sides of the conduit 108, some of which would then end up on the humidity sensor 110. In order to prevent this happening a protruding lip 112 in the conduit 108 located above the humidity sensor 110 can be used to deflect liquid water to flow around the sensing assembly.

[0029] In a medical environment it is important to be able to sterilise the humidity sensor. Traditional methods such as autoclaving can be very harsh on a humidity sensor. Preferably the sensor assembly 11 would be able to survive autoclaving using steam at 136 DEG C. Other common methods of sterilising a probe are to immerse the probe in a disinfectant. Preferably the sensor assembly 11 would survive this treatment.

[0030] Another way of sterilising the heated humidity sensor would be to heat it above the pasteurisation temperature of common pathogens (bacteria and viruses). The hardiest bacteria, Legionella, can be killed by temperatures of 60 DEG C. Preferably the temperature of the sensor is high enough that it kills common pathogens. Alternatively the temperature of the sensor is raised to a high temperature at turn-on to kill pathogens. Alternatively the sensor is periodically heated to a high temperature to kill pathogens.

[0031] Another less desirable way of preventing cross-contamination between patients caused by the sensing assembly 11 is to enclose it in a vapour permeable membrane which does not allow the passage of pathogens. For a humidity sensor probe, the semi permeable membrane could be a cap which fits over the probe and attaches to the probe, or alternatively it could be attached to the hole in the tube which the humidity probe fits into.

[0032] A further way to reduce the potential of cross-contamination would be to construct the sensor assembly out of bactericidal plastic.

[0033] When a humidity sensor is used as part of a humidity control system it is important to be able to detect whether the humidity sensor is functioning correctly or not. This is particularly important if the humidity sensor is used to control a medical humidifier, because excessive levels of absolute humidity can result in patient burns and inadequate levels can cause drying of bodily tissues.

[0034] There are several ways of detecting whether the described sensing assemblies are giving incorrect readings. One way is to remove or reduce the power being supplied to heater 2 to drop the temperature of assembly 11. When the relative humidity reaches 100% we should have reached the dewpoint temperature of the gas, and this can be measured using temperature sensor 3. If the absolute humidity corresponding to this dewpoint is substantially different from the absolute humidity measured by the sensor in normal operation then the sensor is faulty.

[0035] If water has covered the surface of sensor 1 then the sensor will read 100% relative humidity. If 100% relative humidity is measured, the amount of heating being supplied to heater 2 can be increased so that the temperature of assembly 11 increases. If the 100% relative humidity reading remains after the sensor has been heated to a sufficiently high temperature, then the sensor can be judged to be faulty (or covered in water).

[0036] If the sensor is found to be faulty then the power to heater 2 can be discontinued, and the temperature sensor 3 used to give an estimate of the dewpoint of the gas. This can be converted to an absolute humidity figure assuming 100% relative humidity. The true absolute humidity will only be equal or less than the estimated absolute humidity, so this method provides an upper limit on the humidity control to prevent patient burns.

[0037] When a medical humidifier is used with a respiratory ventilator, flow rate and absolute humidity of the gas 14 can change rapidly in a cyclic manner. These changes typically happen faster than the response time of the humidity sensor 1, which gives a "time average" of the humidity surrounding it. However in these situations it is often desirable to know certain parameters such as the peak level of humidity or the average humidity during the inspiratory part of the flow cycle.

[0038] If certain parameters related to the flow rate are known, either through instantaneous flow measurement or through knowledge of other flow parameters, it is possible to mathematically combine this knowledge with the reading from the humidity sensor. This allows estimation of certain key humidity parameters, such as average absolute humidity during the inspiratory part of the flow cycle. The algorithm required could use an equation to estimate the value of the required parameter, or it could use a look up table.

[0039] Flow can be measured directly using a flow rate sensor, e.g. by measuring heat loss from a heated body. The heated humidity sensor as described is such a heated body, and the amount of power required to keep the sensor assembly at a particular temperature will give an indication of the gas rate. Alternatively a separate flow sensor could be used, or this information may be obtained electronically from the ventilator.